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UNITED STATES

Title: **MICROWAVE SWITCH HOUSING ASSEMBLY**

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Title: MICROWAVE SWITCH HOUSING ASSEMBLY

FIELD OF THE INVENTION

This invention relates to a microwave switch and more particularly to an improved microwave switch housing assembly that reduces spurious resonant spikes in the isolation and insertion loss characteristics between unconnected waveguide ports.

BACKGROUND OF THE INVENTION

Microwave switches are used in a variety of applications. For example, in satellite technology, microwave rotary switches (R-switches) and C-switches are widely used as redundant switches to connect a spare device when an active device malfunctions. Typically, large numbers of R-switches and C-switches are employed in a satellite system.

FIG. 1 illustrates the cross-section of a typical microwave R-switch assembly **10** includes a housing **2** (also known as a "stator") having waveguide ports **14A**, **14B**, **14C** and **14D** and a hollow cylindrical interior **16**, and a cylindrical rotor **18** within the housing **2**. Rotor **18** typically has three waveguide paths, a straight central waveguide passage **11**, and two curved waveguide passages **8** and **12** that connect various waveguide ports depending on the specific position of rotor **18** within housing **2**. An actuator (not shown) is used to move the rotor to various predetermined positions. Also, in microwave R-switches and C-switches, it is necessary to provide a physical clearance gap between the rotor and the housing so that the rotor may be rotated within the housing. As shown, a physical clearance gap **G** between the outer surface of the rotor **18** and the inner surface of the housing **2** exists to allow the rotor **18** to rotate unobstructed within housing **2**.

When an electromagnetic signal is propagating from a connected port **14B** at one end of a switched-through waveguide passage **11** to another

connected port **14D** at the other end of the waveguide passage **11**, leakage of some of the electromagnetic signal through clearance gap **G** typically causes the unconnected ports **14A** and **14C** to show an electromagnetic signal, thus degrading the isolation and the insertion loss performance of the microwave switch. Essentially, the gap **G** acts as a transmission line and since the gap **G** encompasses the entire circumference of the rotor **18**, the electromagnetic signal can be indicated at various ports within housing **2**. Also, the not-switched-through waveguide passages **8** and **12** and the inner surface of housing **2** adjacent to waveguide passages **8** and **12** form a volume resonator. If the frequency of the signal passing through the switched-through waveguide passage **11** is close to the resonant frequency of these volume resonators, a signal will appear at the unconnected ports **14A** and **14C** characterized by a spurious narrow spike in the isolation and insertion loss characteristics around the resonant frequency.

It is important to achieve a high degree of mutual isolation of unconnected ports **14A**, **14B**, **14C** and **14D**. For example, in the case of redundancy circuit networks for application within satellite systems, the ratio of the power occurring at a port that is not connected any other port (e.g. **14A**), to the power supplied to a port (e.g. **14B**) that is connected with another port (e.g. **14D**), should be at least as low as approximately –60 dB. This power ratio requirement is applicable to R-switches having any number of ports **14**. Mutual isolation of unconnected ports is conventionally achieved in two ways.

One approach is to narrow the gap **G** in order to reduce the electromagnetic signal leakage through gap **G**. However, this approach is limited by mechanical and thermal requirements and reliability concerns. Specifically, if the gap is narrowed too much, it is not possible to provide housing assembly **10** that functions at an acceptable level over a reasonable range of operating temperatures due to thermal expansion characteristics of rotor **18** and housing **2**.

Another approach is to provide longitudinal and circumferential grooves on the surface of the rotor and/or by providing grooves on the inner

surface of the housing. For example, in U.S. Patent Nos. 3,155,923 to Persson, 4,649,355 to Ullman, and 6,218,912 to Mayer, the isolation of unconnected ports can be improved using such methods and result in a ratio of even less than –60 dB. However, the use of such grooves on the inner surface of the housing does not appear in practice to eliminate the appearance of the spurious narrow spike. The inventors have determined that in practice, the spurious narrow spike still can have an amplitude in the range –35 to –40 dB. In addition, the provision of longitudinal and circumferential grooves adds to the complexity and manufacturing cost of producing housing assembly **10**.

BRIEF SUMMARY OF THE INVENTION

In one aspect the present invention provides a microwave switch housing assembly for operation in a selected frequency range, comprising:

(a) a housing;

(b) a rotor rotatably mounted within said housing;

(c) at least one waveguide passage in said rotor;

(d) said housing having ports formed therein so that in a first position of said rotor, said waveguide passage connects said ports and in a second position of said rotor, said waveguide passage is unconnected to said ports;

(e) a power absorbing element located within one of said housing and said rotor such that said power absorbing element is positioned adjacent to one end of said waveguide passage when said rotor is in said second position;

(f) said power absorbing element being capable of absorbing electromagnetic energy in said frequency range, so as to reduce

the tendency of said waveguide passage to act as a volume resonator when said rotor is in said second position.

Further aspects and advantages of the invention will appear from the following description taken together with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the present invention, and to show more clearly how it may be carried into effect, reference will now be made, by way of example, to the accompanying drawings which show some examples of the present invention, and in which:

FIG. 1 is a cross-sectional schematic view of a prior art microwave R-switch showing potential leakage paths;

FIG. 2 is a cross-sectional view of an example microwave R-switch of the present invention;

FIGS. 3A, 3B, 3C and 3D are perspective views of various channels utilized within the example microwave switches of FIGS. 2 and 8;

FIGS. 4A, 4B, 4C, and 4D are perspective views of various power absorbing elements utilized within the example microwave switches of FIGS. 2 and 8;

FIG. 5A is a cross-sectional view of the example microwave switch of FIG. 2 where the rotor is rotated to a first position;

FIG. 5B is a cross-sectional view of the example microwave switch of FIG. 2, with the rotor is rotated to a second position;

FIG. 5C is a cross-sectional view of the microwave switch of FIG. 2, with the rotor is rotated to a third position;

FIG. 5D is a cross-sectional view of the microwave switch of FIG. 2, with the rotor is rotated to a fourth position;

FIGS. 6A and 6B are graphs illustrating the isolation performance of the microwave R-switch of FIG. 2 in the switch positions shown in FIGS. 5A and 5C;

FIGS. 6C and 6D are graphs illustrating the isolation performance of the microwave R-switch of FIG. 2 in the switch positions shown in FIGS. 5B and 5D;

FIGS. 7A and 7B are graphs illustrating the insertion loss and return loss performance of the microwave R-switch of FIG. 2 in the switch positions shown in FIGS. 5A and 5C;

FIGS. 7C and 7D are graphs illustrating the insertion loss and return loss performance of the microwave R-switch of FIG. 2 in the switch positions shown in FIGS. 5B and 5D;

FIG. 8 is a cross-sectional view of another example microwave R-switch of the present invention;

FIG. 9A is a cross-sectional view of the example microwave switch of FIG. 8 where the rotor is rotated to a first position;

FIG. 9B is a cross-sectional view of the example microwave R-switch of FIG. 8, with the rotor is rotated to a second position;

FIG. 9C is a cross-sectional view of the microwave switch of FIG. 8, with the rotor is rotated to a third position; and

FIG. 9D is a cross-sectional view of the microwave switch of FIG. 8, with the rotor is rotated to a fourth position.

It will be appreciated that for simplicity and clarity of illustration, elements shown in the figures have not necessarily been drawn to scale. For example, the dimensions of some of the elements may be exaggerated relative to other elements for clarity. Further, where considered appropriate, reference

numerals may be repeated among the figures to indicate corresponding or analogous elements.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 2 is a cross-sectional view of an example microwave R-switch assembly **100** built in accordance with the present invention. Microwave switch **100** includes a housing **102** having an internal open space **115** and waveguide ports **104A**, **104B**, **104C** and **104D**, and a rotor **106** disposed within the internal open space of housing **102**. Rotor **106** includes curved waveguide passages **108, 112** and straight waveguide passage **110**. Each waveguide passage **108, 110, 112,** is designed to selectively line up with waveguide ports **104A**, **104B**, **104C** and **104D** as rotor **106** rotates within housing **102**. An actuator (not shown) is used in a conventional way to move the R-switch to various predetermined positions. Channels **116a**, **116b**, **116c**, **116d** are formed within housing **102** and are adapted to house power absorbing elements **118a**, **118b**, **118c**, **118d** manufactured out of material that absorbs electromagnetic power. As rotor **106** rotates within housing **102**, four predetermined switch positions can be achieved. Power absorbing elements **118a**, **118b**, **118c**, **118d** are positioned within channels **116a, 116b, 116c, 116d** and used to absorb electromagnetic power generated by the resonant oscillations present within unconnected waveguide passages as will described.

Rotor **106** includes center portions **114a** and **114b** and side portions **115a** and **115b**. Center portion **114a** is positioned between waveguide passages **108** and **110**, and center portion **114b** is positioned between waveguide passages **110** and **112**. Side portions **115a** and **115b** are positioned on the other side of waveguide passages **108** and **112** from center portions **114a** and **114b**. Waveguide passages **108**, **110** and **112** when aligned with ports **104A**, **104B**, **104C**, and **104D** in housing **102**, allow propagation of electromagnetic energy (i.e. provide a electromagnetic wave propagation path),

having a wavelength that corresponds to the dimension of the ports. Center portions **114a** and **114b** and side portions **115a** and **115b** are preferably manufactured out of conductive material (e.g. a suitable metal such as aluminum, copper, brass or another metal plated with gold or silver, or chemical coated surface) to establish a waveguide transmission line with no crosstalk between waveguide passages.

Housing **102** is a conventional machined microwave switch housing containing waveguide ports **104A**, **104B**, **104C**, and **104D** and a rotor-accepting cylindrical cavity **115**. Ports **104A**, **104B**, **104C**, **104D**, that are not coupled through a waveguide path will be described as mutually isolated. Ports **104A**, **104B**, **104C** and **104D**, that are coupled through a waveguide path will be described as mutually connected. Conventional waveguide connecting flanges (not shown) are easily attached to housing **102** at appropriate port locations as conventionally known. Housing **102** also contains four longitudinal channels **116a**, **116b**, **116c**, **116d** that are adapted to house four longitudinal power absorbing elements **118a**, **118b**, **118c** and **118d**. As shown in FIG. 2, channels **116a**, **116b**, **116c** and **116d** are positioned radially outwardly from the internal open space of housing **102**. Each channel **116a**, **116b**, **116c** and **116d** has an open side that communicates with the internal open space of housing **102**. Each channel **116a**, **116b**, **116c** and **116d** is positioned within housing **102** such that power absorbing elements **118a**, **118b**, **118c**, **118d** are located within channels **116a**, **116b**, **116c**, **116d** are able to absorb electromagnetic power between mutually isolated ports such that resonant oscillations are suppressed. Housing **102** is preferably manufactured from aluminum, however it should be understood that other materials could be utilized (e.g. a suitable metal such as aluminum, copper, brass or another metal plated with gold or silver, or chemical coated surface).

Channels **116a**, **116b**, **116c**, and **116d** are preferably formed with a substantially rectangular cross-sectional profile (FIG. 3A). However, it should be

understood that channels **116a**, **116b**, **116c**, and **116d** may have various cross-sectional profiles including rectangular with rounded corners, oval, ellipse, semi or partial cylindrical (FIG. 3B and 3C) or triangular (FIG. 3D) and other various geometries. Further, it is preferred for the width and height of each channel opening to be substantially similar to the width and height of the ends of the waveguide passages **108**, **110**, **112** such that channels **116a**, **116b**, **116c** and **116d** can be dimensionally aligned with waveguide passages **108**, **110** and **112** when rotor **106** is suitably rotated within housing **102**. However, it should be understood that housing assembly **100** can still be beneficially utilized with channels **116a**, **116b**, **116c**, and **116d** having a widths and/or lengths that differ by as much as 20 to 25% from the respective widths and lengths of the ends of the waveguide passages.

Power absorbing elements **118a**, **118b**, **118c**, **118d** comprise power absorbing load material that is suited to absorb substantial amounts of electromagnetic power. Accordingly, power absorbing elements **118a**, **118b**, **118c**, **118d** change the boundary conditions for not-switched-through wave-guide passages **110** (FIG. 5A, 5C) or **108** and **112** (FIG. 5B, 5D) in rotor **106** when passage ends are blocked by the inner surface of a housing **102**. Power absorbing elements **118a**, **118b**, **118c**, **118d** positioned within channels **116a**, **116b**, **116c**, **116d** change the boundary conditions on the ends of the waveguide passages **108**, **110**, **112** from perfectly conductive surfaces, that fully reflect electromagnetic waves to walls that are non-conductive and absorb electromagnetic power.

Thus, passages **108**, **110**, **112** that previously would act as volume resonators are transformed into a piece of a waveguide transmission line loaded on both ends. Power absorbing elements **118a**, **118b**, **118c**, **118d** preferably entirely absorb the electromagnetic power of oscillations in a particular not-switched-through waveguide passage although it is also sufficient for power absorbing elements **118a**, **118b**, **118c**, **118d** to partially absorb such

electromagnetic power such that the magnitude of the spurious spike on the isolation characteristic is reduced down to the noise floor. Power absorbing elements **118a**, **118b**, **118c**, **118d** is manufactured from material that functions over the same, or wider, frequency band as microwave switch **100** (e.g. MF124-500 can operate as a load element over the frequency range 1-18GHz).

Power absorbing elements **118a**, **118b**, **118c**, **118d** are positioned within and secured within channels **116a**, **116b**, **116c**, **116d** using conventional means (e.g. bond epoxy, casting, insert molding, pressure fit, threaded mating etc.). While it is preferred to utilize power absorbing elements **118a**, **118b**, **118c**, **118d** that have a rectangular cross-section (FIG. 4A), it should be understood that the cross-section of power absorbing elements **118a**, **118b**, **118c**, and **118d** could also be of many other shapes such as cylindrical (FIG. 4B), semicircular (FIG. 4C), or square (FIG. 4D).

An important electrical parameter for waveguide switches is the measurement of isolation performance. Isolation performance is a measurement of electromagnetic signal leakage into the waveguide ports that are mutually isolated (i.e. unconnected) when the switch is in a particular position. It desirable to achieve high isolation performance within a waveguide switch assembly. Isolation performance is determined by rotor and housing configuration, number of half wavelengths in a waveguide between adjacent waveguide paths and the availability of space for choke sections.

As shown in FIG. 5A, a leakage path **LPA** as shown by dotted lines can exist between rotor **106** and the housing **102**. Signal leakage will occur along the dotted line of **LPA** in between mutually isolated ports **104A**, **104B**, **104C**, **104D** and cause signal to enter into unconnected waveguide passages, which is in the case of FIG. 5A, waveguide passage **110**. Unconnected waveguide passage **110** is restricted at both ends by the walls of housing **102**. That is, the unconnected waveguide passage **110** and the adjacent walls of housing **102** form a cavity that can act as a volume resonator. The frequency of oscillation of

this resonator depends on the geometrical dimensions of the resonator volume that is defined by waveguide passage **110** and housing **102** wall (i.e. width, height and length). A change in one of these dimensions will alter the frequency of oscillation. The dominant modes of the oscillation are TE101, TE102 and TE201. Since the second digit of the index of these modes is "0", changes in the waveguide height will not affect the resonance frequency. However, a change in the height and/or in the width of the volume resonator will produce a change in path impedance that will cause additional reflect of the signal and as a result degradation of the return loss. Changing the length will necessitate the increase in the length of rotor **106** that introduces increased switch size, mass and manufacturing costs.

In the case where channels **116a**, **116b**, **116c**, and **116d** have a rectangular-shaped opening of substantially the same width and length as the ends of the rectangular waveguide passages **108**, **110**, **112**, the length of the volume resonator that is associated with an unconnected waveguide passage **108**, **110**, **112** is effectively increased. Since the path length is increased due to the additional path length associated with channels **116a**, **116b**, **116c**, **116d**, the resonator frequency is lowered. The resonant frequency may be lowered sufficiently so that leakage of transmitted signals along the gap no longer induce the volume resonator to resonate at the operating frequency band of a switch, but in many cases a resonance still may occur, causing a spurious resonant spike as mentioned. Since power absorbing elements **118a**, **118b**, **118c**, **118d** are also present within channels **116a**, **116b**, **116c**, **116d** adjacent to unconnected waveguide passages **108**, **110**, **112**, power absorbing elements **118a**, **118b**, **118c**, **118d** change the boundary conditions on the inner walls of housing **102** absorbing electromagnetic power that is generated by resonant frequency oscillations in the unconnected waveguide passages **108**, **110**, **112** and transform these waveguide passages **108**, **110**, **112**, into a transmission line as discussed above.

For example, as shown in FIG. 5A, when waveguide passage **108** connects ports **104A** and **104B** and waveguide passage **112** connects ports **104C** and **104D**, the leakage paths **LPA** and **LPB** are created (shown as dotted lines). Since power absorbing elements **118b** and **118d** are positioned within leakage paths **LPA** and **LPB** adjacent to the ends of waveguide passage **110**, conditions for complete reflection of electromagnetic power within the volume resonator between the walls of housing **102** no longer exist. That is, the volume resonator is transformed into a piece of a transmission line that is terminated at both ends which suppresses resonant oscillations. Accordingly, the unconnected waveguide path **110** no longer operates as a volume resonator. The result is that the spurious resonant spike within the isolation characteristic and the corresponding spike on the insertion loss characteristic both fall below the noise floor and for practical purposes are removed and improved isolation conditions between mutually unconnected ports **104A**, **104B**, **104C**, **104D** result.

Housing assembly **100** will now be described in more detail in its four main operational positions. FIG. 5A shows housing assembly **100** in a first position where rotor **106** is positioned within housing **102** such that waveguide passage **108** switched-through and connects ports **104A** and **104B** and waveguide passage **112** switched-through and connects ports **104C** and **104D**. Leakage path **LPA** (FIG. 5A) is created between ports **104A** and **104D** and leakage path **LPB** (FIG. 5A) is created between port **104B** and **104C**. Waveguide passage **110** is unconnected and restricted by the walls of housing **102**, and specifically terminates at cavities **116b**, **116d**. As described, waveguide passage **110** and the walls of housing **102** create a cavity that can act as a volume resonator supplied by stray electromagnetic signals received from leakage paths **LPA** and **LPB**. In this first position, power absorbing elements **118b** and **118d** absorb electromagnetic power generated by resonant frequency oscillations in waveguide passage **110**. Accordingly, the unconnected waveguide path **110** cannot operate as a volume resonator and resonant oscillations are dramatically

reduced within the volume resonator. The result is that the spurious resonant spike within the isolation characteristic and the corresponding spike on the insertion loss characteristic both fall below the noise floor and for practical purposes are removed and improved isolation conditions between mutually unconnected ports **104A** and **104D** and **104B** and **104C** result.

FIG. 5B shows housing assembly **100** in a second position where waveguide passage **110** is switched-through and connects ports **104A** and **104C**. Leakage path **LPC** is created between ports **104A** and **104B**, leakage path **LPD** is created between port **104B** and **104C**, leakage path **LPE** is created between ports **104C** and **104D**, leakage path **LPF** is created between port **104D** and **104A**. Waveguide passages **108** and **112** are unconnected and restricted by the walls of housing **102**, and specifically terminate at cavities **116a**, **116b** and **116c**, **116d**, respectively. As described, waveguide passages **108** and **112** and the walls of housing **102** create cavities that can act as a volume resonators supplied by stray electromagnetic signals received from leakage paths **LPC**, **LPD** and **LPE**, **LPF**, respectively. In this second position, power absorbing elements **118a**,**118b** and **118c**,**118d** absorb electromagnetic power generated by resonant frequency oscillations in waveguide passages **108** and **112**, respectively. Accordingly, the unconnected waveguide paths **108** and **112** cannot operate as volume resonators and resonant oscillations are dramatically reduced within these volume resonators. The result is that the spurious resonant spike within the isolation characteristic and the corresponding spike on the insertion loss characteristic both fall below the noise floor and for practical purposes are removed and improved isolation conditions between mutually unconnected ports **104B** and **104D** result.

FIG. 5C shows housing assembly **100** in a third position where waveguide passage **108** is switched-through and connects ports **104B** and **104C** and waveguide passage **112** is switched-through and connects ports **104A** and **104D**. Leakage path **LPG** is created between ports **104A** and **104B** and leakage

path **LPH** is created between port **104C** and **104D**. Waveguide passage **110** is unconnected and restricted by the walls of housing **102**, and specifically terminates at cavities **116a, 116c**. As described, waveguide passage **110** and the walls of housing **102** create a cavity that can act as a volume resonator supplied by stray electromagnetic signals received from leakage paths **LPG** and **LPH**. In this third position, power absorbing elements **118a** and **118c** absorb electromagnetic power generated by resonant frequency oscillations in waveguide passage **110**. Accordingly, the unconnected waveguide path **110** cannot operate as a volume resonator and resonant oscillations are dramatically reduced within the volume resonator. The result is that the spurious resonant spike within the isolation characteristic and the corresponding spike on the insertion loss characteristic both fall below the noise floor and for practical purposes are removed and improved isolation conditions between mutually unconnected ports **104A** and **104B** and **104C** and **104D** result.

FIG. 5D shows housing assembly **100** in a fourth position where waveguide passage **110** is switched-through and connects ports **104B** and **104D** only. Leakage path **LPI** is created between ports **104A** and **104B**, leakage path **LPJ** is created between port **104B** and **104C**, leakage path **LPK** is created between ports **104C** and **104D**, leakage path **LPL** is created between port **104D** and **104A**. Waveguide passages **108** and **112** are unconnected and restricted by the walls of housing **102**, and specifically terminate at cavities **116a**, **116d** and **116b**, **116c**, respectively. As described, waveguide passages **108** and **112** and the walls of housing **102** create cavities that can act as a volume resonators supplied by stray electromagnetic signals received from leakage paths **LPI**, **LPL** and **LPJ**, **LPK**, respectively. In this fourth position, power absorbing elements **118a**,**118d** and **118b**,**118c** absorb electromagnetic power generated by resonant frequency oscillations in waveguide passages **108** and **112**, respectively. Accordingly, the unconnected waveguide paths **108** and **112** cannot operate as volume resonators and resonant oscillations are dramatically reduced within

these volume resonators. The result is that the spurious resonant spike within the isolation characteristic and the corresponding spike on the insertion loss characteristic both fall below the noise floor and for practical purposes are removed and improved isolation conditions between mutually unconnected ports **104A** and **104C** result.

As shown in FIGS. 6A, 6B, 6C, and 6D, experiments were conducted to determine relative isolation performance as between switch assembly **100** containing microwave assembly housing **102** with and without power absorbing elements **118a**, **118b**, **118c**, **118d**. As will be discussed, the use of power absorbing elements **118a**, **118b**, **118c**, **118d** within housing **102** results in the spurious resonant spike associated with the isolation characteristic being suppressed down to the noise floor for all switch positions.

Specifically, FIG. 6A illustrates the isolation performance characteristic **250** associated with switch assembly **102** without power absorbing elements and FIG. 6B illustrates the isolation performance characteristic **255** associated with switch assembly **102** with power absorbing elements. Isolation characteristics **250** and **255** are measured when switch assembly **100** is in the first and third switch positions discussed above (e.g. in the positions shown in FIGS. 5A and 5C). In these switch positions, waveguide passages **108** and **112** are switched through and waveguide passage **110** is not-switched-through. In the first switch position (FIG. 5A) isolation performance is measured at port **104B** when port **104C** is the input port and **104D** is the termination port and at port **104D** when port **104A** is the input port and **104B** is the termination port. In the third switch position (FIG. 5C) isolation performance is measured at port **104B** when port **104A** is the input port and **104D** is the termination port and at port **104D** when port **104C** is the input port and port **104B** is the termination port. As can be seen in FIG. 6A, in the absence of power absorbing elements **118a**, **118b**, **118c**, **118d** in housing **102**, a spurious spike **252** is produced within the isolation performance characteristic **250**. Spurious spike **252** appears within

isolation performance characteristic **250** at 14.18 GHz. As shown in FIG. 6B, when power absorbing elements **118a, 118b, 118c, 118d** are utilized within housing **102**, there is no discernable spurious spike within the isolation loss characteristic **250**.

FIG. 6C illustrates the isolation performance characteristic **300** associated with switch assembly **102** without power absorbing elements and FIG. 6D illustrates the isolation performance characteristic **305** associated with switch assembly **102** with power absorbing elements. Isolation characteristics **300** and **305** are measured when switch assembly **100** is in the second and fourth switch positions discussed above (e.g. in the positions shown in FIGS. 5B and 5D) resulting in an identical isolation characteristic due to device symmetry. In these switch positions, waveguide passage **110** is switched through and waveguide passages **108, 112** are not-switched-through. In the second switch position (FIG. 5B) isolation performance is measured at port **104B** or **104D** when port **104A** is the input port and **104C**. In the fourth switch position (FIG. 5D) isolation performance is measured at port **104A** or **104C** when port **104D** is the input port and **104B** is the termination port. As can be seen in FIG. 6C, in the absence of power absorbing elements **118a, 118b, 118c, 118d** in housing **102**, a spurious spike **302** is produced within the isolation performance characteristic **300**. Spurious spike **302** appears within isolation performance characteristic **300** at 10.85 GHz. As shown in FIG. 6D, when power absorbing elements **118a, 118b, 118c, 118d** are utilized within housing **102**, there is no discernable spurious spike within the isolation loss characteristic **305**.

As shown in FIGS. 7A, 7B, 7C and 7D, experiments were also conducted to determine the insertion loss and return loss characteristics for housing **102** within and without power absorbing elements **118a, 118b, 118c, 118d**. As will be discussed, the use of power absorbing elements **118a, 118b, 118c, 118d** within housing **102** results in the spurious resonant spike associated

with the insertion loss characteristic being suppressed down to the noise floor for all switch positions.

Specifically, FIG. 7A illustrates the isolation performance characteristic **350**, **351** associated with switch assembly **102** without power absorbing elements and FIG. 7B illustrates the isolation performance characteristic **355**, **356** associated with switch assembly **102** having power absorbing elements. Insert and return characteristics **350** and **355** are measured when switch assembly **100** is in the first and third switch positions discussed above (e.g. in the positions shown in FIGS. 5A and 5C). In these switch positions, waveguide passages and **112** are switched through and waveguide passage **110** is not-switched-through. In the first switch position (FIG. 5A), the insert and return performance characteristic is measured using **104A** as the input port and **104B** as the output port. In the third switch position (FIG. 5C), the insert and return performance characteristic is measured using **104B** as the input port and **104C** as the output port or using **104A** as the input port and **104D** as the output port. As can be seen in FIG. 7A, in the absence of power absorbing elements **118a**, **118b**, **118c**, **118d** in housing **102**, a spurious spike **352** is produced within the isolation loss characteristic **350**. Spurious spike **352** appears within isolation loss characteristic **350** at 14.18 GHz. As shown in FIG. 7B, when power absorbing elements **118a**, **118b**, **118c**, **118d** are utilized within housing **102**, there is no discernable spurious spike within the isolation loss characteristic **305**.

FIG. 7C illustrates the isolation performance characteristic **400**, **401** associated with switch assembly **102** without power absorbing elements and FIG. 7D illustrates the isolation performance characteristic **405**, **406** associated with switch assembly **102** having power absorbing elements. Isolation characteristics **400** and **405** are measured when switch assembly **100** is in the second and fourth switch positions discussed above (e.g. in the positions shown in FIGS. 5B and 5D). In these switch positions, waveguide passage **110** is switched through

and waveguide passages **108, 112** are not-switched-through. In the second switch position (FIG. 5B), the insert and return performance characteristic is measured using port **104A** as the input port and **104C** as the output port. In the fourth switch position (FIG. 5D), the insert and return performance characteristic is measured using port **104B** as the input port and **104D** as the output port. As can be seen in FIG. 7C, in the absence of power absorbing elements **118a**, **118b**, **118c**, **118d** in housing **102**, a spurious spike **402** is produced within the insertion loss characteristic **400**. Spurious spike **402** appears within insertion loss characteristic **300** at 10.85 GHz. As shown in FIG. 7D, when power absorbing elements **118a**, **118b**, **118c**, **118d** are utilized within housing **102**, there is no discernable spurious spike within the insertion loss characteristic **405**.

Power absorbing elements **118a**, **118b**, **118c**, and **118d** can have various depths and widths as long as the surface of power absorbing elements **118a**, **118b**, **118c**, and **118d** that faces the internal space of housing **102** does not protrude into the internal space of housing **102**. This is to ensure that the rotation of rotor **106** is not obstructed and to allow for sufficient operational clearance between the outer surface of rotor **106** and the inner surface of housing **102** in the case of temperature variations. In terms of length, it is preferred to utilize power absorbing elements **118a**, **118b**, **118c**, **118d** that have length that is substantially similar to the length of the ends of waveguide passages **108**, **110**, **112**. That is, preferably power absorbing elements **118a**, **118b**, **118c**, and **118d** substantially fill channels **116a**, **116b**, **116c**, and **116d** lengthwise, it is possible to operate housing assembly **100** to advantage using power absorbing elements **118a**, **118b**, **118c**, **118d** that do not completely fill channels **116a**, **116b**, **116c**, **116d** and which are positioned at various positions along channels **116a**, **116b**, **116c**, **116d** (e.g. at either end or at various positions in between). It has been experimentally determined that favourable results can be obtained by using power absorbing elements **118a**, **118b**, **118c**, **118d** that are within 50 to 100% of the length of channels **116a**, **116b**, **116c**, **116d**.

Also, it should be understood that various combinations of power absorbing elements **118a**, **118b**, **118c**, **118d** of various cross-sections and channels **116a**, **116b**, **166c**, **116d** of various cross-sections are possible, such as for example, power absorbing elements **118a**, **118b**, **118c**, **118d** having square cross-sections within channels **116a**, **116b**, **116c**, **116d** of rectangular cross-section. Also, it should be understood that various combinations of power absorbing elements and channel pairs could be utilized. That is, for example, housing assembly **100** could have one channel that is of a cylindrical cross-section and another channel that is of a rectangular cross-section each with differently shaped power absorbing elements.

FIG. 8 is a cross-sectional view of another example microwave R-switch housing assembly **200** built in accordance with the present invention. Common elements between housing assembly **200** and housing assembly **100** will be denoted by the same numerals but with one hundred added thereto. Microwave switch **200** includes a housing **202** having an internal open space **215** and waveguide ports **204A**, **204B**, **204C** and **204D**, and a rotor **206** disposed within the internal open space of housing **202**. Rotor **206** includes waveguide passages **208**, **210** and **212** that are designed to selectively line up with waveguide ports **204A**, **204B**, **204C** and **204D** as rotor **206** rotates within housing **202**. In addition, longitudinal channels **216a**, **216b**, **216c**, **216d**, **216e**, and **216f** are formed within rotor **206** as shown in FIG. 8. Channels **216a**, **216b**, **216c**, **216d**, **216e** and **216f** are adapted to house power absorbing elements **218a**, **218b**, **218c**, **218d**, **218e** and **218f**. As rotor **206** rotates within housing **202**, four predetermined switch positions can be achieved. Ports **204** that are not coupled through a waveguide path are again described as mutually isolated ports **204**. Ports **204** that are coupled through a waveguide path are again described as mutually connected ports **204**. Power absorbing elements **218a**, **218b**, **218c**, **218d**, **218e**, **218f** are positioned within channels **216a**, **216b**, **216c**, **216d**, **216e**, **216f** and absorb electromagnetic power propagating through the gap between

rotor **206** and housing **202**. The gap may act as a feeding line connecting switch ports **204A**, **204B**, **204C** and **204D** with a not-switched-through waveguide passage **208**, **210**, or **212** depending on the position of switch **200**. A not-switched waveguide passage **208**, **210**, or **212** may act as a volume resonator. Power absorbing elements **218a**, **218b**, **218c**, **218d**, **218e, 218f** positioned within channels **216a**, **216b**, **216c**, **216d**, **216e**, **216f** prevents the gap between rotor **206** and housing **202** from behaving as a feeding line and the gap does not excite resonant oscillations generated by the resonant oscillations in the non-switched-through waveguide passages **208**, **210**, or **212** as will be described.

It should be understood that in contrast to the switch assembly **100** of FIG. 2 where power absorbing elements **118a**, **118b**, **118c**, **118d** are used to change the boundary conditions on the ends of the not-switched-through waveguide passages **108**, **110** or **112**, power absorbing elements **218a**, **218b**, **218c**, **218d**, **218e, 218f** of switch assembly **200** of FIG. 8, change conditions for signal propagation in the feeding line represented by the gap between rotor **206** and housing **202**.

Housing assembly **200** will now be described in its four main operational positions. FIG. 9A shows housing assembly **200** in a first position where rotor **206** is positioned within housing **202** such that waveguide passage **208** is switched-through and connects ports **204A** and **204B** and waveguide passage **212** is switched-through and connects ports **204C** and **204D**. A leakage path **LPAA** is created between ports **204A** and **204D** and a leakage path **LPBB** is created between port **204B** and **204C**. Waveguide passage **210** is unconnected and terminates at housing **202**. In this first position, power absorbing elements **218b**, **218c**, **128e** and **218f** are positioned adjacent to the ends of unconnected waveguide passage **210** and absorb electromagnetic power propagating through the leakage paths **LPAA** and **LPBB** formed between switch ports **204A**, **204D** and between switch ports **204B**, **204C** to waveguide passage **210**. Accordingly, the leakage paths no longer represent an effective

transmission feeding line to excite resonant frequency oscillations in the not-switched-through waveguide passage **210**. Accordingly, the unconnected waveguide path **210** cannot operate as a volume resonator and resonant oscillations are dramatically reduced within the volume resonator. The result is that the spurious resonant spike within the isolation characteristic and the corresponding spike on the insertion loss characteristic both fall below the noise floor and for practical purposes are removed. Accordingly, improved isolation conditions between mutually unconnected ports **204A** and **204D** and **204B** and **204C** result.

FIG. 9B shows housing assembly **200** in a second position where waveguide passage **210** is switched-through and connects ports **204A** and **204C**. A leakage path **LPCC** is created between ports **204A** and **204B**, a leakage path **LPDD** is created between ports **204B** and **204C**, a leakage path **LPEE** is created between port **204C** and **204D**, and a leakage path **LPFF** is created between ports **204D** and **204A**. Waveguide passages **208** and **212** are unconnected and each is terminated at the walls of housing **202**. In this second position, power absorbing elements **218a, 218b**, and **218f** are positioned adjacent to the ends of unconnected waveguide passage **208** and power absorbing elements **218c, 218d**, and **128e** are positioned adjacent to the ends of unconnected waveguide passage **212**. Each of these power absorbing elements absorb electromagnetic power propagating through the leakage paths **LPCC**, **LPDD**, **LPEE**, and **LPFF** formed between switch ports **204A**, **204B** and switch ports **204B**, **204C**, switch ports **204C**, **204D**, and switch ports **204D**, **204A** to waveguide passages **208** and **212** as shown in FIG. 9B. Accordingly, the leakage paths no longer represent an effective transmission feeding line to excite resonant frequency oscillations in the not-switched-through waveguide passage **210**. Accordingly, the unconnected waveguide paths **208** and **212** cannot operate as volume resonators and resonant oscillations are dramatically reduced within the volume resonator. The result is that the spurious resonant spike within the isolation characteristic and

the corresponding spike on the insertion loss characteristic both fall below the noise floor and for practical purposes are removed. Accordingly, improved isolation conditions between mutually unconnected ports **204B** and **204D** result.

FIG. 9C shows housing assembly **200** in a third position where waveguide passage **208** is switched-through and connects ports **204B** and **204C** and waveguide passage **212** is switched-through and connects ports **204A** and **204D**. A leakage path **LPGG** is created between ports **204A** and **204B** and a leakage path **LPHH** is created between port **204C** and **204D**. Waveguide passage **210** is unconnected and terminates at housing **202**. In this third position, power absorbing elements **218b**, **218c**, **218e** and **218f** are positioned adjacent to the ends of unconnected waveguide passage **210** and absorb electromagnetic power propagating through the leakage paths **LPGG** and **LPHH** formed between switch ports **204A**, **204B** and between switch ports **204C**, **204D** to waveguide passage **210**. Accordingly, the leakage paths no longer represent an effective transmission feeding line to excite resonant frequency oscillations in the not-switched-through waveguide passage **210**. Accordingly, the unconnected waveguide path **210** cannot operate as a volume resonator and resonant oscillations are dramatically reduced within the volume resonator. The result is that the spurious resonant spike within the isolation characteristic and the corresponding spike on the insertion loss characteristic both fall below the noise floor and for practical purposes are removed. Accordingly, improved isolation conditions between mutually unconnected ports **204A** and **204B** and **204C** and **204D** result.

FIG. 9D shows housing assembly **200** in a fourth position where waveguide passage **210** is switched-through and connects ports **204B** and **204D**. A leakage path **LPII** is created between ports **204A** and **204B**, a leakage path **LPJJ** is created between ports **204B** and **204C**, a leakage path **LPKK** is created between port **204C** and **204D**, and a leakage path **LPLL** is created between ports **204D** and **204A**. Waveguide passages **208** and **212** are unconnected and

each terminate at the walls of housing **202**. In this second position, power absorbing elements **218a, 218b**, and **228f** are positioned adjacent to the ends of unconnected waveguide passage **208** and power absorbing elements **218c, 218d**, and **128e** are positioned adjacent to the ends of unconnected waveguide passage **212**. Each of these power absorbing elements absorb electromagnetic power propagating through the leakage paths **LPII**, **LPJJ**, **LPKK**, and **LPLL** formed between switch ports **204A**, **204B** and switch ports **204B**, **204C**, switch ports **204C**, **204D**, and switch ports **204D**, **204A** to waveguide passages **208** and **212** as shown in FIG. 9D. Accordingly, the leakage paths no longer represent an effective transmission feeding line to excite resonant frequency oscillations in the not-switched-through waveguide passages **208**, **212**. Accordingly, the unconnected waveguide paths **208** and **212** cannot operate as volume resonators and resonant oscillations are dramatically reduced within the volume resonator. The result is that the spurious resonant spike within the isolation characteristic and the corresponding spike on the insertion loss characteristic both fall below the noise floor and for practical purposes are removed. Accordingly, improved isolation conditions between mutually unconnected ports **204A** and **204C** result.

While the channels **116a**, **116b**, **116c**, **116d** of housing assembly **100** have been described as being provided within housing **102** and while channels **216a**, **216b**, **216c**, **216d**, **216e**, **216f** have been described as being provided within rotor **206**, it should be understood that it is possible to combine these approaches. Specifically, housing assembly could include some channels within the housing and some in the rotor, positioned in such a way that the power absorbing elements housed within channels would be positioned adjacent one end of an unconnected waveguide passage.

Also, it should be understood that the above discussion of the present invention has only referred, for simplicity, to the specific example of a four-port R-switch having three waveguide passages. It will be obvious to

persons of ordinary skill in the art how to modify the embodiments to R-switches having a different number of ports and/or a different number or shape of waveguides. Also, it should be understood that the underlying invention could be applied to any other type of microwave switch including, but not limited to, C-switches, T-switches, SPDT switches. Such modifications are intended to be within the scope of the present invention.

While certain features of the invention have been illustrated and described herein, many modifications, substitutions, changes, and equivalents will now occur to those of ordinary skill in the art. It is, therefore, to be understood that the appended claims are intended to cover all such modifications and changes as fall within the true spirit of the invention.